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Effect of Soil Applied Silicon on Gas Exchange Parameters, Growth and Ion Content of Maize under Alkaline Stress

Gokula Priya Natarajan[1], Malayappa Venkataraman Sriramachandrasekharan[1*], Rengarjan Manivannan[1] and Muthu Arjuna Samy Prakash[2]

[1]Dept. of Soil Science and Agricultural Chemistry, [2]Dept. of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai university, Annamalai Nagar, Tamilnadu (608 002), India

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Corresponding Author

Malayappa Venkataraman Sriramachandrasekharan
e-mail: ram_uthrat@yahoo.com

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Abstract

A pot experiment was conducted to understand the effect of soil applied silicon on maize crop growth under alkaline stress. The treatment consists of silicon levels (kg ha^{-1}) – 0, 100 and 150 and alkaline stress levels (mM) – 0, 25, 50, 75. The pots were arranged in completely randomized block design in factorial arrangement with three replications. The result revealed that the shoot and root length and chlorophyll content of maize were reduced with increasing alkaline stress. The percent reduction due to alkaline stress on shoot and root length was to tune of 3.6 to 15.8 and 8.9 to 35.8, respectively and chlorophyll content 11.2 to 35.7. The sodium ion content increased, but potassium content and K Na^{-1} ratio decreased with alkaline stress. The gas exchange parameters viz., photosynthetic rate, stomatal conductance and transpiration rate were significantly decreased with alkalinity levels. The adverse effect of alkalinity on maize was turnround with intervention of soil applied silicon. The percent increase due to silicon intervention ranged from 4.3 to 12.6 in photosynthetic rate, 4.5 to 14.5 in stomatal conductance, 6.3 to 21.4 in transpiration rate, 7.0 to 20.9 and 8.4 to 29.3 in shoot and root potassium, 19.4 to 33.5 and 20.6 to 55.9 in shoot and root K Na^{-1}. The percent decrease in sodium concentration in shoot and root ranged from 8.6 to 14.2 and 4.3 to 23.7. Between 100 and 150 kgs of silicon applied, the desired result was achieved with 150 kg Si ha^{-1}. It is recommended to apply 150 kg Si ha^{-1} to maneuver the ill effects of alkalinity on maize.

Keywords: Alkalinity, gas parameters, growth, ions, maize, silicon

1. Introduction

Abiotic stress can adversely affect the agricultural productivity leading to physiological and biochemical damage to crops (Yavas and Unay, 2017). Abiotic stress such as salinity-alkalinity stress is an adverse obstacle in the production of agricultural crops and severely affects the growth of plants. Globally, it has been estimated that approximately 3.97×10^{8} ha of land is affected by salt and 4.34×10^{8} is alkaline (Martinez-Beltran and Manzur, 2005). A number of studies have shown that alkaline stress is more dangerous than saline stress, owing to its additional high pH stress (Chen et al., 2012; Radi et al., 2012). High pH value may lead to reduction in seed germination, destruction of the root cell structure, change in the nutrient availability and disorder in nutrient uptake, and thus resulting in a significant decrease in the yield of agricultural plants (Gao et al., 2014).

Article History

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Plants can use silicon (Si), acquired as a nutrient through their roots, to alleviate the impacts of an impressive range of abiotic stress including salinity, metal toxicity, nutrient imbalance, temperature and water stress (Cookie and Leishman, 2016). Liang et al. (2007) identified four main mechanisms of Si use for abiotic stress alleviation in higher plants: stimulation of antioxidant systems in plants, complexation or co-precipitation of toxic metal ions with Si, immobilization of toxic metal ions in growth media, uptake processes and compartmentation of metal ions within the plants. Silicon may alleviate salt stress by inhibition of transport of sodium ions to the leaves and specific accumulation of these ions in the roots (Tuna et al., 2008). The use of an exogenous silicon source is an alternative to ameliorate the stress generated, and in the case of this study, the silicon is effective to mitigate the damage to the photosynthetic pigments, number of stomata, and leaf blade thickness (Rezende et al., 2017).

Certain cereal crops especially from Poaceae and Cyperaceous families accumulate large amount of Si which helps to improve their growth and development during stress conditions. Being a member of Poaceae family, maize can accumulate silicon (Amin et al., 2014) and thus it is a popular crop for studies on the useful impacts of Si under environmental pressures (Malcovska et al., 2014). The productivity of maize decreases due to alkalinity in tropics and subtropics. Thus, a pot experiment was carried out to understand the effect of soil applied silicon on maize growth under alkaline soil.

2. Materials and Methods

2.1. Study site

A pot experiment was conducted in the pot culture yard, located in the Department of Soil Science and Agriculture Chemistry, Faculty of Agriculture, Annamalai University during 2019 to understand the effect of soil applied silicon on gas exchange parameters, growth and ion content of maize plant in alkaline soils.

2.2. Method of data collection

Processed bulk soil samples belonging to kondal series (*Typic Haplusterts)* was taken as experimental soil. The experimental soil was clay loam in texture, pH–8.3, EC–0.67 dSm^{-1}, organic carbon–5.2 g kg^{-1}, Exchangeable sodium –2.89 cmol kg^{-1}, Exchangeable potassium-5.9 cmol kg^{-1}, ESP–8.9(%), $KMnO_4$–N–265 kg ha^{-1}, Olsen–P–21.5 kg ha^{-1}, NH_4OAc–K–196.5 kg ha^{-1} and available silicon–37.9 mg kg^{-1}. The experiment consists of 12 treatments with three levels of silicon (0(Si_0), 100(Si_{100}), 150(Si_{150}) kg ha^{-1}) applied through sodium metasilicate and four levels of alkaline stress (0(Al_0), 25(Al_{25}), 50(Al_{50}), 75(Al_{75}) mM) applied through sodium carbonate. The 36(4×3×3) pots were arranged in completely randomized design in factorial arrangement with three replications involving test crop maize hybrid var. CO 8. Recommended dose of fertilizers (150:75:75 kgs of NPK ha^{-1}) through urea, superphosphate and muriate of potash was applied uniformly to all the pots as solution culture. The maize crop was grown upto vegetative stage. The biometric observations like shoot and root length were recorded. The SPAD-502 meter, a hand-held device was used for the rapid, accurate and non-destructive measurement of leaf chlorophyll concentrations. The shoot and root were analyzed for potassium and sodium concentration following standard procedure using flame photometer.

Gas exchange parameters viz., leaf photosynthetic rate (Pn), transpiration rate (Tr) and stomatal conductance (Gs) were measured from two uppermost fully expanded leaves from all the plants using LICOR-6400 XT Portable Photosynthetic system (Lincoln, USA) and expressed as µmol m^{-2} s^{-1}, µmol m^{-2} s^{-1} and mmol m^{-2} s^{-1}, respectively. All the estimations and measurements were made between 10.00–11.00 a.m. from each treatment.

The data was subjected to statistical analysis to get meaningful explanation for the variability obtained for various characters due to treatments following Gomez and Gomez (1976). Regression analysis and correlation was worked out to find out the selective variation between variables.

3. Results and Discussion

3.1. Shoot and root length and chlorophyll content

Soil application of silicon at different levels and varying levels of alkaline stress together or independently. did cause a significant (p<0.05) influence on shoot and root length and chlorophyll content of maize over control (Table 1). The maize crop experienced inimical effect on shoot and root length and chlorophyll content, as it experienced alkaline stress. The shoot and root length decreased with increase in alkalinity levels. The percent reduction in shoot length ranged from (3.6 to 15.8) and root length (8.9 to 35.8) with increase of 25 to 75 mM alkalinity levels. Similarly, chlorophyll content as SPAD value decreased from 21.6 (25 mM) to 12.6 (75 mM). The harmful effect of alkali stress on shoot and root length and chlorophyll content was offset by application of silicon and the effect was maximum with 150 kg ha^{-1}. Beneficial effect of silicon on shoot growth at varying levels of alkaline stress ranged from 4.96 to 9.32% (25 mM), 4.34 to 8.9% (50 mM) and 4.75 to 9.3% (75 mM). The percent improvement in root length ranged from 4.44 to 10.2 (25 mM), 5.6 to 11.2 (50 mM) and 6.3 to 12.2 (75 mM). Irrespective of silicon levels, shoot and root length decreased with increase with alkaline levels and maximum reduction was noticed with 75 mM (44.2 cm, 22.2 cm) in the absence of silicon. The per cent improvement in SPAD value with silicon levels ranged from 6.3 to 12.6 (25 mM), 9.4 to 16.9 (50 mM) and 11.1 to 21.4 (75 mM). In normal soil, graded dose of silicon improved the SPAD value to the tune of 6.6 to 10.2%.

As expected, adverse effects occurred for maize plant growth when they were grown in alkaline stress condition as obtained in non-alkaline soil. In the present study, shoot length reduced

Table 1: Effect of soil application of silicon under alkalinity levels on shoot and root length and chlorophyll

Alkaline levels (mM)	Shoot length (cm)				Root length (cm)				Chlorophyll (SPAD)			
	Silicon levels (kg ha^{-1})				Silicon levels (kg ha^{-1})				Silicon levels (kg ha^{-1})			
	0	100	150	Mean	0	100	150	Mean	0	100	150	Mean
0	52.3	55.7	58.9	55.6	34.6	38.0	39.6	37.4	19.6	20.9	21.6	20.7
25	50.4	52.9	55.1	52.8	31.5	32.9	34.7	33.0	17.4	18.5	19.6	18.5
50	48.3	50.4	52.6	50.4	24.9	26.3	27.7	26.3	16.0	17.5	18.7	17.4
75	44.2	46.3	48.3	46.3	22.2	23.6	24.9	23.6	12.6	14.0	15.3	13.9
Mean	48.8	51.3	53.7		28.3	30.2	31.7		16.4	17.7	18.8	
	Si	Al	Si×Al		Si	Al	Si×Al		Si	Al	Si×Al	
SEd	0.2	0.3	0.5		0.2	0.2	0.4		0.1	0.1	0.2	
CD (p=0.05)	0.5	0.6	1.0		0.4	0.5	0.8		0.2	0.3	0.5	

from 3.6 to 15.8%, root length reduced from 8.9 to 35.8% and chlorophyll content reduced from 11.2 to 35.7% (Figure 1) due to different alkalinity levels. The growth of salt stressed plant is mostly limited by the osmotic effect of salt, irrespective of their capacity to exclude salt that results in reduced growth rates and stomatal conductance (James et al., 2008). Decrease in root and shoot growth might be due to ability of inhibiting uptake of water and essential nutrients, decrease in photosynthates, enzymatic processes and protein synthesis (Munns, 2002). Chlorophylls control the photosynthetic potential of plants by capturing light energy from the sun

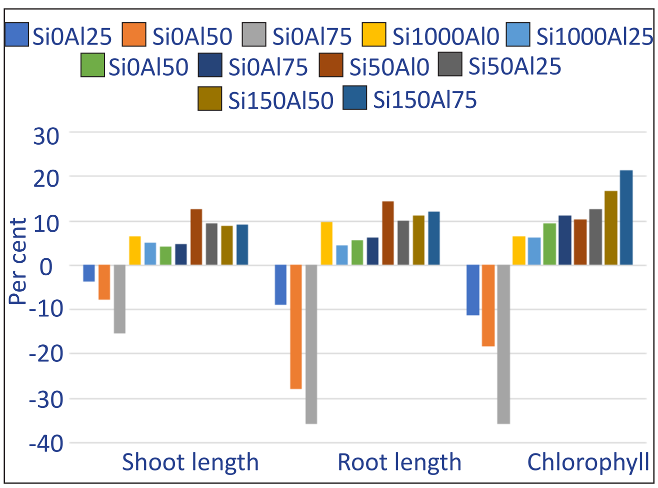

Figure 1: Percent change in shoot and root growth and chlorophyll content of maize due to alkalinity levels and silicon fertilization

and represent one of the most important photosynthetic pigments. The decrease in chlorophyll content is an indicator of oxidative stress and response of pigment photo oxidation as well as degradation of chlorophyll. The reduced chlorophyll content might be due to Mg^{2+} precipitation that results in the degradation of green pigment (Shi and Zhao, 1997) or reduced enzymatic activity of protochlorophyllide reductase and α- amino levulinic acid dehydratase, as both are involved in chlorophyll biosynthesis, formation of proteolytic enzymes such as chlorophyllase which is responsible for chlorophyll degradation as well as damage to photosynthetic apparatus (Kaya et al., 2006). In the present study, significant negative correlation was noticed between chlorophyll and Na^+ concentration shoot (r=-0.931**). Silicon intervention through soil application added to alkaline stress soil overcame the negative effect and it resulted in increase in shoot and root length and chlorophyll content with silicon levels and maximum effect was noticed with 150 kg Si/ha. The effect of silicon was to the tune of 4.3 to 12.6 % in shoot length, 4.5 to 14.5% in root length and 6.3 to 21.4 % in chlorophyll (Figure 1). Silicon fertilization increased chlorophyll in maize leaves grown in stressed and non-stressed soil because it increased activity of tonoplast H^+-ATPase and H-PPase, minimized arrived damage to chloroplast, increased chlorophyll and photosynthetic activity (Liang et al., 2005).

3.2. Gas exchange parameters

Examination of variance (p<0.05) showed that both alkalinity levels and silicon levels had significant effect on gas exchange parameters (Table 2). Photosynthetic rate (Pn), stomatal conductance (Gs) and transpiration rate (Tr) decreased with alkaline stress levels and maximum reduction in photosynthetic rate (5.50 μmolm^{-2}s^{-1}), stomatal conductance (0.039 mmol m^{-2} s^{-1}) and in transpiration rate (1.92 mmol m^{-2} s^{-1}) was noticed with 75mM alkaline stress in the absence of silicon. Soil supplied with silicon caused a significant improvement in Pn, Gs and Tr both under normal and alkali stress soil. At all alkaline stress levels, gas parameters in maize leaves showed upward trend with silicon and it was noticed up to 150 kg Si/ha. Percent improvement in photosynthetic rate, stomatal conductance and transpiration rate with silicon was 27.3 to 32.7, 16.7 to 33.3, 13.8 to 28.1 (25 mM), 26.7 to 45.6, 16.3 to 28.6, 23.3 to 52.4 (50 mM) and 33.1 to 61.3, 12.8 to 28.2, 7.3 to 18.2 (75 mM). In normal soil, silicon application caused 18.6 to 39.2 %, 33.3 to 41.6% and 21.6 to 33.2% increase in photosynthetic rate, stomatal conductance

Table 2: Effect of soil application of silicon under alkalinity levels on maize photosynthetic rate, stomatal conductance and transpiration rate

Alkaline levels (mM)	Photosynthetic rate (μmol m^{-2} s^{-1})				Stomatal conductance (μmol m^{-2} s^{-1})				Transpiration rate (mmol m^{-2} s^{-1})			
	Silicon levels (kg ha^{-1})				Silicon levels (kg ha^{-1})				Silicon levels (kg ha^{-1})			
	0	100	150	Mean	0	100	150	Mean	0	100	150	Mean
0	9.70	11.5	13.5	11.6	0.060	0.080	0.085	0.075	3.01	3.66	4.01	3.59
25	9.27	11.8	12.3	11.1	0.054	0.063	0.072	0.063	2.53	2.88	3.24	2.88
50	7.42	9.40	10.8	9.20	0.049	0.057	0.063	0.056	2.06	2.54	3.14	2.58
75	5.50	7.32	8.87	7.23	0.039	0.044	0.050	0.044	1.92	2.06	2.27	2.08
Mean	7.97	9.98	11.36		0.050	0.061	0.067		2.38	2.78	3.19	
	Si	Al	Si x Al		Si	Al	Si x Al		Si	Al	Si x Al	
SEd	0.09	0.10	0.18		0.005	0.006	0.011		0.07	0.08	0.15	
CD (*p*=0.05)	0.19	0.21	0.38		0.011	0.013	0.023		0.15	0.18	0.31	

and transpiration rate, respectively over control

Increase in sodium carbonate concentration in the soil was associated with progressive fall in photosynthetic rate, stomatal conductance and transpiration rate in maize leaves relative to untreated control. The percent decrease in photosynthetic rate (4.4 to 43.3), stomatal conductance (10 to 35) and transpiration rate (15 to 36) was noticed with alkaline stress levels. (Figure 2). Strong linear regressive

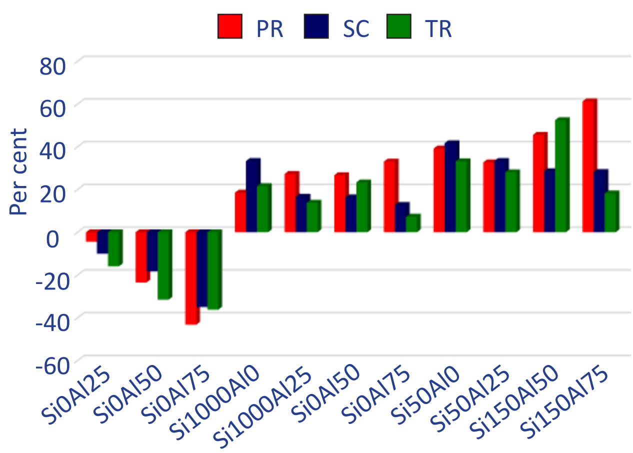

Figure 2: Percent change due to alkalinity levels and silicon fertilization on photosynthetic rate (PR), stomatal conductance (SC) and transpiration rate (TR) of maize

model of the increasing alkaline concentration (independently variable) and the decrease of photosynthetic rate in the leaf (r^2=0.9751), stomatal conductance in the leaf (r^2 =0.9901) and transpiration rate in the leaf (r2=0.9752) as dependent variable was noticed in the present study (Figure 3). The reduction in photosynthetic rate is due to a) Dehydration of cell membranes which reduce their permeability to carbon dioxide b) Salt toxicities c) reduction of CO_2 supply due to hydro active closure of stomata d) enhanced senescence induced by salt and e) change of enzymatic activities induced by changes

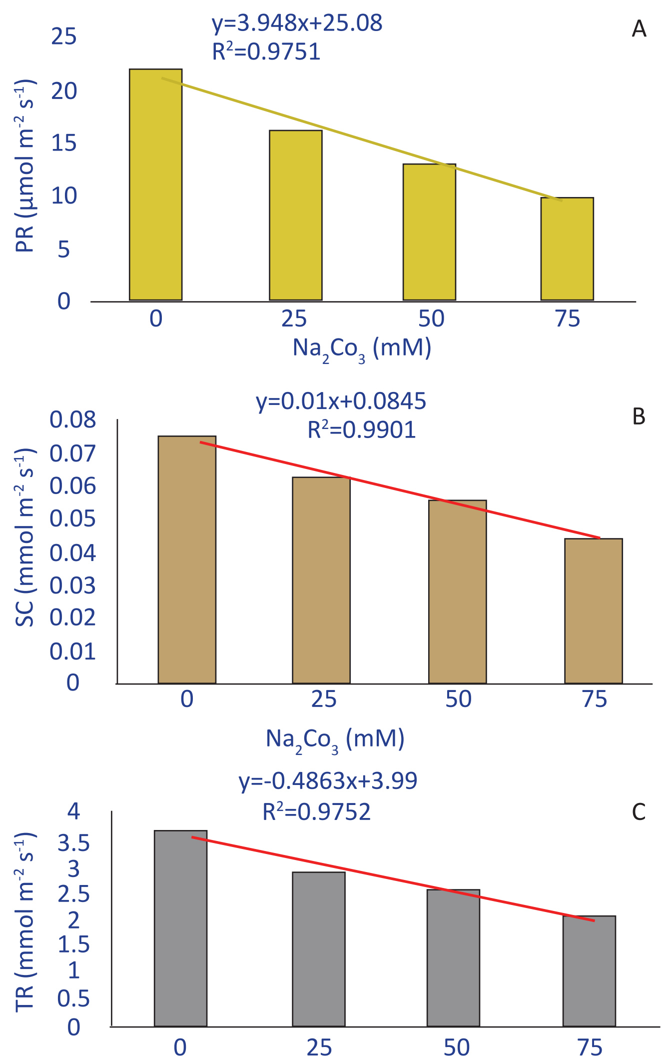

Figure 3: Effect of levels of alkali stress and interlinear relationship on a) Photosynthetic rate; b) Stomatal conductance and c) Transpiration rate

in cytoplasmic structure (Qin et al., 2018). Salt stress affected the diffusion of CO_2 into the leaves due to closed stomata and decreased stomatal and mesophyll conductance (Pinero et al., 2014). Stomata closure in response to salinity stress generally occurs due to decreased leaf turgor and atmospheric vapour pressure, along with root-generated chemical signals (Chaves et al., 2009). Reduction in photosynthesis under salinity stress occurs because plants close their stomata to reduce water loss, which in turn leads to a reduction in leaf transpiration rates and a lowering of internal CO_2 concentrations in leaves. Liu et al. (2018) reported 44% decrease in transpiration rate in alfalfa due to alkaline stress. Soil application of silicon nullified the negative effect of alkaline stress on gas parameters. Silicon improved photosynthetic rate (18.5 to 61.3%), stomatal conductance (12.8 to 41.7%) and transpiration rate (7.3 to 33.2%) and maximum effect was realized with 150 kg Si/ha (Figure 2). Silicon supplementation might increase photosynthetic rate and boost the production of chlorophyll a and b and also associated with positive effect on stomatal conductance and transpiration under isolated and multiple stress condition (Yao et al., 2011). Exogenous application of Si improved the stomatal conductance due to the increase in the stomata number and stomata size in salinity stressed okra (Liu et al., 2019). Improvement in transpiration rate on silicon fertilization could be due to Si can provide a physical barrier of silica gel on the outer layers of leaves, roots and vascular tissues of stems, which reduces evapotranspiration (Ma and Yamaji, 2006). Several researchers indicated that silicon might improve photosynthetic rate (Shen et al., 2010), stomatal conductance (Xie et al., 2014) and transpiration rate (Ahmadi and Siosemarch, 2005) both under stressed and non-stressed condition. Xie et al. (2014) noted that optimal dose of silicon application of 150 kg ha^{-1} increased photosynthetic activities of maize.

3.3. Sodium and potassium concentration and k na^{-1} ratio

Potassium and sodium concentration in maize shoot and root was markedly influenced by the alkalinity stress levels and silicon levels either alone or together over non-stressed soil and non-silicon (Table 3). Sodium concentration in maize shoot and root shot up with compartmental increase in salt stress level. Sodium content in shoot and root increased with alkali stress levels and the maximum value was noticed with 75 mM (31.6 ppm) and (59.1 ppm), respectively. High sodium content in maize leaves grown in different stressed soil was moderated under the influence of silicon inclusion and their effect was significant at 5% level. At all alkali stress levels, sodium content decreased with linear increase in silicon levels. The percent reduction in sodium content in shoot and root was 9.5 to 12.9, 7.1 to 22.7 (25 mM), 11.9 to 16.6, 9.1 to 23.1 (50 mM) and 14.2 to 19, 10.3 to 23.7 (75 mM), respectively. shoot and root potassium content showed a progressive fall with stress levels. The lowest shoot (38.5 ppm) and root potassium (14.9 ppm) content was recorded with 75mM in the non-silicon supplied soil. Shoot and root potassium content increased with silicon priming at all concentration and maximum value was noticed with 150 kg Si ha^{-1}. The percent improvement in shoot and root potassium content was 7.7 to 16.1, 29.3 to 50.6 (25 mM), 11.3 to 20.9, 14.8 to 29 (50 mM) and 7.0 to 13, 10.1 to 20.1 (75 mM), respectively.

Table 3: Effect of soil application of silicon under alkalinity levels on maize photosynthetic rate, stomatal conductance and transpiration rate

Alkaline levels (mM)	Sodium content (shoot)				Sodium content (root)				Potassium content (shoot)				Potassium content (shoot)			
	Silicon levels (kg ha^{-1})				Silicon levels (kg ha^{-1})				Silicon levels (kg ha^{-1})				Silicon levels (kg ha^{-1})			
	0	100	150	Mean	0	100	150	Mean	0	100	150	Mean	0	100	150	Mean
0	18.6	17.0	16.2	17.3	46.7	44.4	42.3	44.5	49.6	53.5	56.2	53.1	21.4	23.2	25.7	23.4
25	20.1	18.2	17.5	18.6	51.1	47.5	39.5	46.0	44.2	47.6	51.3	47.7	16.4	21.2	24.7	20.7
50	27.7	24.4	23.1	25.1	56.3	51.2	43.3	50.3	40.6	45.2	49.1	44.9	16.2	18.6	20.9	18.6
75	31.6	27.1	25.6	28.1	59.1	53.0	45.1	52.4	38.5	41.2	43.5	41.1	14.9	16.4	17.9	16.4
Mean	24.5	21.7	20.6		53.5	49.0	42.6		43.2	46.9	50.0		17.2	19.9	22.3	
	Si	Al	Si×Al		Si	Al	Si×Al		Si	Al	Si×Al		Si	Al	Si×Al	
SEd	0.2	0.2	0.3		0.1	0.1	0.2		0.2	0.2	0.3		0.2	0.2	0.4	
CD (*p*=0.05)	0.3	0.4	0.7		0.3	0.3	0.5		0.3	0.4	0.7		0.4	0.5	0.8	

Potassium sodium ratio in maize shoot and root was strongly influenced by the action of silicon fertilization and alkaline levels either independently or together over control (Table 4). As the alkali stress levels increased, potassium sodium ratio in maize shoot and root decreased. At all silicon levels, potassium sodium ratio in maize shoot and root decreased with alkaline stress levels and maximum reduction in potassium sodium ratio in shoot (1.22) and root (0.25) was noticed with 75 mM alkaline stress in the absence of silicon. Percent improvement in potassium sodium ratio in shoot and root with silicon was 19.1 to 33.2, 22.2 to 75 (25 mM), 25.9 to 44.9, 24.1 to 65.5 (50

Table 4: Effect of soil application of silicon under alkalinity levels on K Na^{-1} ratio in maize shoot and root

Alkaline levels (mM)	K Na^{-1} ratio in shoot				K Na^{-1} ratio in root			
	Silicon levels (kg ha^{-1})				Silicon levels (kg ha^{-1})			
	0	100	150	Mean	0	100	150	Mean
0	2.77	3.15	3.47	3.13	0.46	0.53	0.61	0.53
25	2.20	2.62	2.93	2.58	0.36	0.44	0.63	0.47
50	1.47	1.85	2.13	1.81	0.29	0.36	0.48	0.37
75	1.22	1.52	1.70	1.48	0.25	0.31	0.40	0.32
Mean	1.91	2.28	2.55		0.34	0.41	0.53	
	Si	Al	Si×Al		Si	Al	Si×Al	
SEd	0.04	0.05	0.09		0.03	0.04	0.07	
CD (p=0.05)	0.09	0.10	0.18		0.07	0.08	0.15	

mM) and 24.6 to 39.3, 24 to 60 (75 mM), respectively. At all alkaline stress levels, potassium sodium ratio in maize shoot and root showed upward trend with silicon fertilization and it was noticed up to 150 kg Si ha^{-1}.

Under salt stress, Na^+ competes with K^+ for uptake into roots (Munns and Tester, 2008). Na^+ content increased with increasing alkalinity. In the present study too, alkalinity increased the shoot and root sodium concentration compared to normal soil. The extent of increase in sodium content in maize shoot ranged from 8.0 to 69.8% and in root 9.4 to 26.6% under varying salt stress level (Figure 4). This caused the reduction in shoot and root growth of maize. To cope up ROS generation due to alkalinity, plant root also absorbs several minerals including essential mineral (K^+) and other nutrient (Na^+) that are toxic to normal growth and development (Luan et al., 2009). Potassium is considered as one of the primary osmotic substances which contribute to osmotic adjustment in many plant species, protein synthesis and enzyme activation (Iannuci et al., 2002). Potassium concentration in the shoot and roots of maize was lower in alkali stressed plant compared to maize plant grown in normal soil. The extent of reduction in potassium concentration was to the tune of 10.9 to 22.4% in shoot and 23.4 to 30.4 % (Figure 4). Potassium starvation regularly accompanies sodium toxicity (Flowers and Lauchli, 1983). Decrease in K^+ concentration in plant tissues grown under salinity stress is well reported phenomenon in different plant species (Tahir et al., 2012). Silicon fertilization enhances sodium tolerance in rice (Kim et al., 2014). Turan et al. (2009) reported that addition of silicon could simultaneously decrease sodium accumulation in shoot and root. The result obtained by previous workers is also seen in the present study. Soil applied silicon has reduced the sodium content in leaf by 8.6 to 14.2% and in root by 4.3 to 23.7%. (Figure 4). Addition of silicon to alkali stress soil increased the potassium concentration to the level of 7.0 to 20.9% in shoot and 8.4 to 29.3% in root (Figure 4). This could be due to stimulating effect of silicon on K through activation of H-ATPase in the membrane (Karmollachaab and Gharineh, 2015). Higher

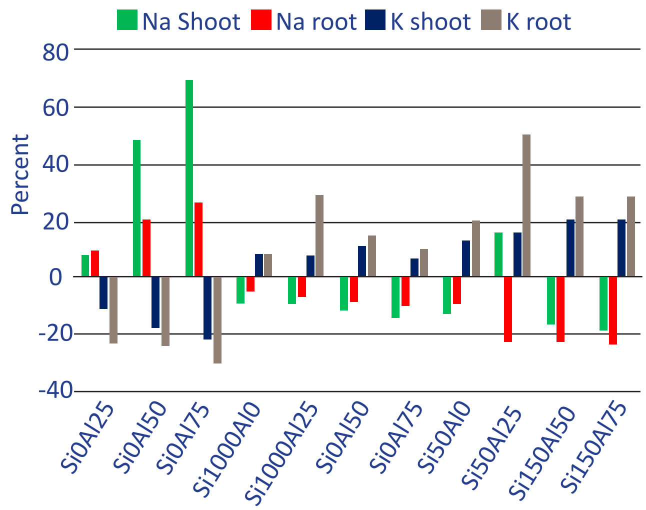

Figure 4: Percent Change in sodium and potassium content in shoot and root of maize due to alkalinity levels and silicon fertilization on

levels of K in the plant are beneficial in achieving better survival with improved growth under salt stress (Umar and Moinuddin, 2002). The optimum concentration of K+ narrows by increasing the amount of Na+ for many reasons such as similarity of Na^+ and K^+ in their physicochemical structure. K^+/Na^+ ratio in shoot and root decreased with alkalinity levels. Masoud Fakhrfeshani et al. (2015) also reported decrease in K^+/Na^+ ratio in *Aeluropus littoralis* grown in alkali stress. Silicon applied through soil application caused increase in K^+/Na^+ ratio in maize plants grown in alkali stress,

4. Conclusion

The growth of maize crop is severely hampered when grown in alkaline stress soil. The gas parameters viz., photosynthetic rate, stomatal conductance, transpiration rate, chlorophyll content and potassium ion in shoot and root in maize were drastically reduced, while sodium content improved when maize was grown in alkaline stressed soil. Silicon fertilization to maize crop improved all the above-mentioned parameters and application of 150 kg Si ha^{-1} was found to be best in growth of maize crop.

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